GPS, GIS & Wireless Technologies for effectively supporting airfield safety including incursion reduction

By:
Paul Cudmore
Eagle Integrated Solutions
Campbellford, Ontario, Canada
866-241-3264
paulc@team-eagle.ca

PRESENTED FOR THE
2010 FAA WORLDWIDE AIRPORT TECHNOLOGY TRANSFER CONFERENCE
Atlantic City, New Jersey, USA

APRIL 2010

Table of Contents

Introduction

Airfield operations have increased in complexity and volume over the past several years due to a number of factors including but not limited to increased regulatory requirements, budget constraints, requirements for more take-offs/landings, training issues & losing experienced airfield operators (retirement for example). The Flight Safety Foundation [1] has indicated that as air traffic is on the rise, issues such as mitigating human error and training are critical to continuing to ensure safe working environments, not to mention the need to adopt new technologies to enhance safety & support an economically viable industry. As such, new tools & resources to help manage the workload and improve its efficiency, while maintaining and or enhancing safety, are appreciated by airport operators.

Background Information

Over the past decade, Global Positioning Systems (GPS) and Geographic Information Systems (GIS) technologies have advanced in terms of reliability, accuracy and cost-effectiveness. These technologies (see Appendix #1 for more detailed information) have become mainstream and are part of our daily lives in our personal vehicles, on our cellular phones and on the internet.

Because the GPS signal is free, it offers a very attractive solution for locating items and or tagging data to fixed items through easy to use graphical interfaces. Although there is a cost to the software and required hardware to utilize this technology, the main ingredient for extremely useful solutions is readily available for airports to take advantage of. “If a picture is worth a thousand words, then GIS is worth a million answers!" [2].

Data movement options are increasing at a rapid rate with more powerful (speed and capacity) than once thought possible outside of military requirements.

The combination of GPS, GIS and wireless data can provide a host of opportunities to improve safety on the airfield. This paper will focus on the specific advances made in using these technologies to further support a safer working environment on the airfield.

Applying GPS, GIS and wireless technologies to airfield safety

From visiting with hundreds of airport operators the following observations have been noted in terms of areas of interest for the above technologies (in order of the progressive way in which the technology can be applied and not necessarily in order of importance):

A. **Increase situational awareness**
    a. Where am I?
        i. This is the basis for staying safe on the airfield
    b. Where are the issues?
        i. Graphically identifying the issues and their related details
B. **Navigation**
    a. How can I get from A to B?

i. Vehicle operators need to know where they are and be better prepared for:
    1. Reduced visibility
    2. Airport restrictions/emergency situations
    3. New to the airport (contractor)

C. Help reduce and or eliminate airfield vehicle incursions

a. Reminders when inspectors are approaching restricted areas
    i. Crossing a hold-line/stop-bar for example
    ii. Especially important for new staff & contractors on-site that don't know the airfield
b. What can we give to a contractor to help?
    i. Must be easy to use and portable

D. Training:

a. It can take months for an inspector/operator/contractor to become familiar with the airfield and effective in their duties and even experienced operators have had issues

E. Management oversight/reporting:

a. Managers want to see where vehicles were and what operations took place yesterday, last night etc.
b. Managers want information at their finger tips, both in tabular format and graphically
c. How can we look at an area, an operator(s) or a circumstance in a critical objective way
d. Information is needed quickly

The use of GPS, GIS and wireless technologies (as required), can help address the above in the following manner:

<u>Increase Situational Awareness</u>

A GPS receiver mounted on a vehicle will collect positional data 24/7/365. When combined with a GIS, this allows the operator to see where they are at all times as well as zoom in/out to the level required to provide the required awareness. Also, as the vehicle moves the map and related assets (if they are available) move with the vehicle.

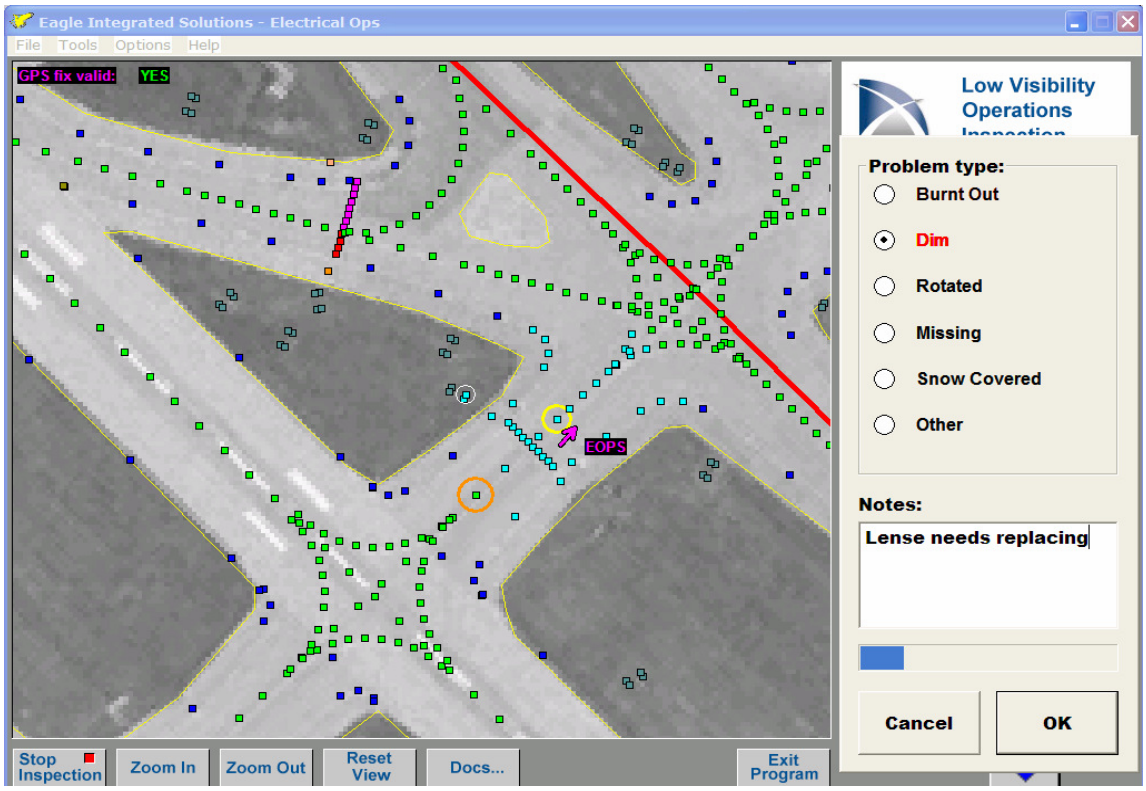


Figure 1. Displaying where you are (the vehicle) on the airfield (Toronto-Pearson International Airport)

Issue Identification

Consider the advantages of "stamping" the exact location of the friction/temperature data as it is collected by/from the equipment. A very accurate location of the data, which is also date/time initialized is now created. This derives many benefits including the ability to objectively demonstrate due diligence (i.e. "As you can see, when the plane landed we had friction/Mu values shown via GPS/GIS on the map of 0.6, 0.7 etc. and an average value of .65"). This information now allows for real-time decision making with both economic and environmental benefits (i.e. we only have to anti-ice the touch down area and not the whole runway). Using the GIS interface as a guide, operators can task chemical applicators to apply chemicals at pre-defined rates in predefined areas. This allows for a greater level of confidence in where and how much chemical is applied.

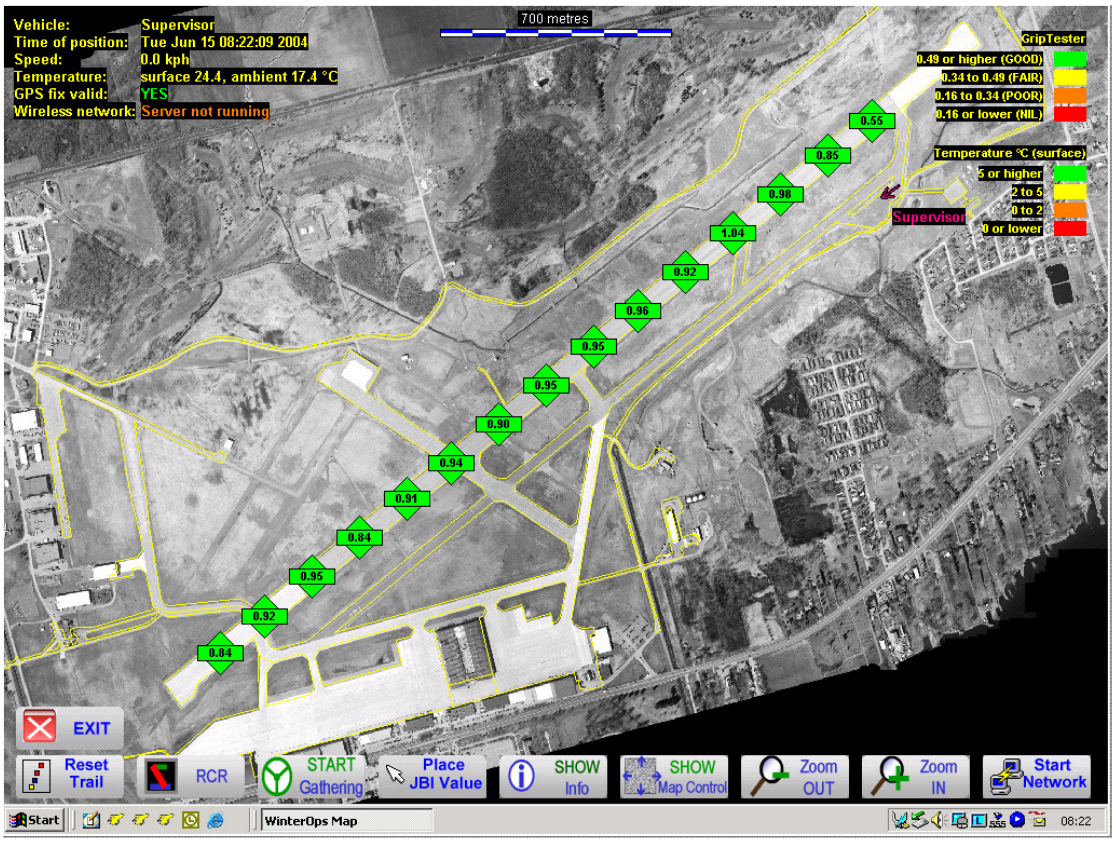


Figure 2. GPS/GIS runway friction, temperature and condition measurement

Navigation

ARFF teams are required to demonstrate the ability to be anywhere on the airfield to respond to emergencies within minutes. Under ideal weather conditions this may be quite possible. Combine elements such as nighttime, snow/fog/heavy rain and safe, effective navigation can easily be compromised. GPS/GIS provides the capabilities of giving the position of the vehicle on the airfield surface, so awareness of where the vehicle is in relation to where it needs to be is available. Combine this with instruction on how to get from "A to B", and you have the capability to drive, watching the progress on the map, while listening to audible commands to help rescue crews get to the incident as quickly as possible. Combining this with the on-board thermal imager provides both the ability to get the required location and see any obstacles in the way. This is a significant improvement from a safety perspective.

In the same fashion, snow teams need to find their way during remarkably difficult and stressful conditions (must get the runway cleared to keep the flow of planes coming in/going out). The lead snow plow/sweeper/blower typically provides the "follow me" capabilities for other equipment. With the ability to see their relative position on the airfield using GPS/GIS, operators can safely and efficiently find their way and guide others if required. Awareness in terms of proximity to fixed assets such as lights and

signs can also provide for benefits in terms of less damage/required repair as the operator can avoid these assets during operations (GPS/GIS would allow for the setup of a reminder notification as the operator approached the light they have perhaps hit/damaged in previous snow events).

Lastly, new trainees can benefit by using a predefined route for say a low-vis airfield inspection which will show them where they are relative to the predefined route, warn them if they are going off-track, remind them of how long they should be taking to complete the route and as detailed below, can be reminded if they are approaching safety areas/hot-spots/incursion areas.

Managing Incursions

Because the location, direction and speed of the vehicle is always known via GPS, it is possible to apply conditions or specific rules when certain criteria are met. For example, if an airfield operator is approaching a hold line/stop bar from the non active side, a geo-fence (geographic zone depicted on the map) can be easily (within 10 seconds) set up so that if the operator enters this area, then a message plays/light flashes/horn sounds to warn the operator of the condition that has been met (i.e. flashing yellow light on the dashboard means that you are approaching a hold line).

Figure 3. Various Geo-zones at an Airport (each zone can have the same settings or not and trigger for all vehicles or just specified ones)

Operators are trained to stop and hold until ATC provides clearance. Other situations such as speeding, approaching another vehicle etc. can also trigger desired responses ahead of time so that the potential for an incident is reduced and or mitigated all together.

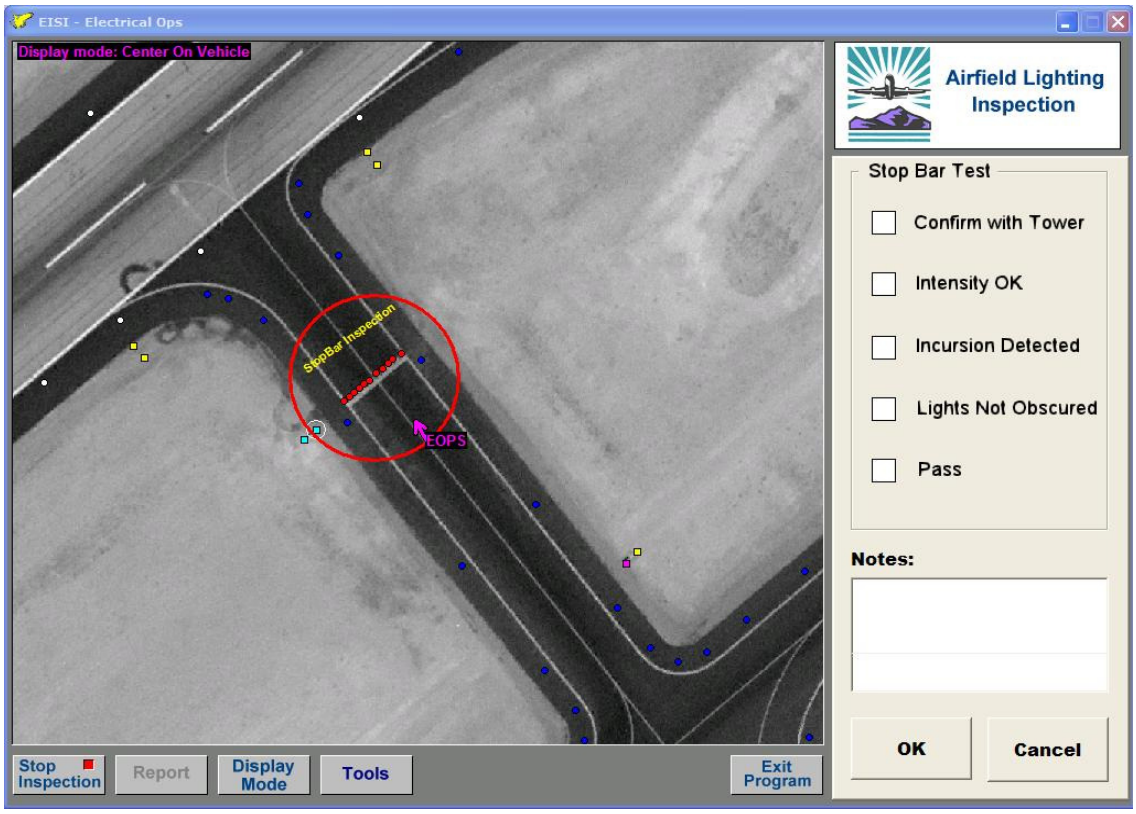


Figure 4. GPS/GIS Incursion warning & Inspection at Stop Bar
(El Paso International Airport)

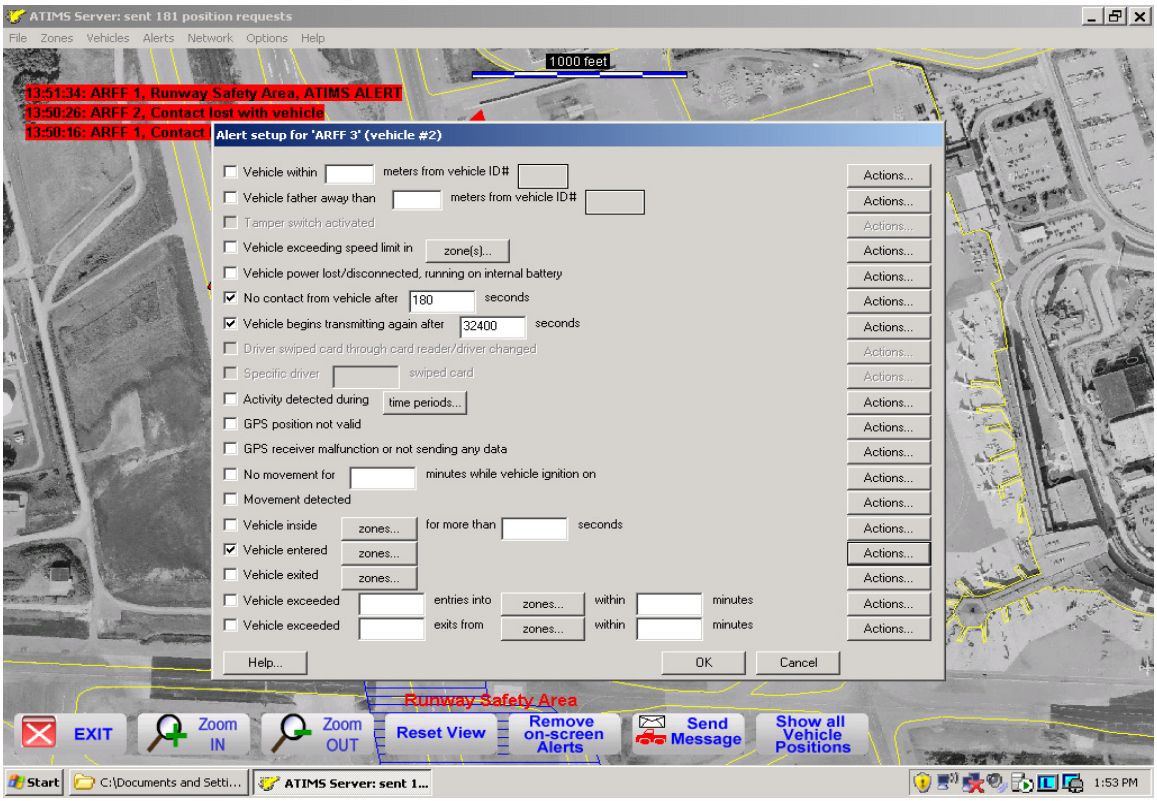


Figure 5. Sample settings and options in order to trigger actions when certain conditions are met

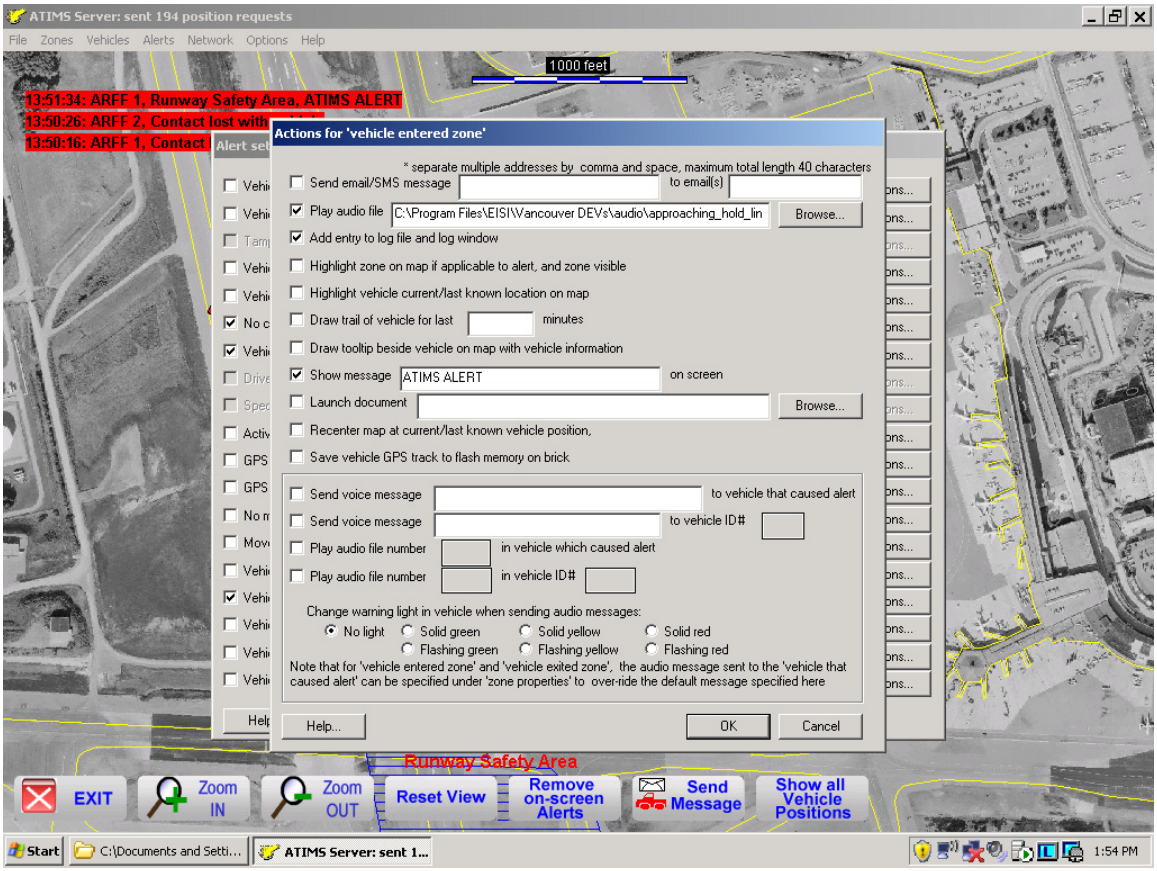
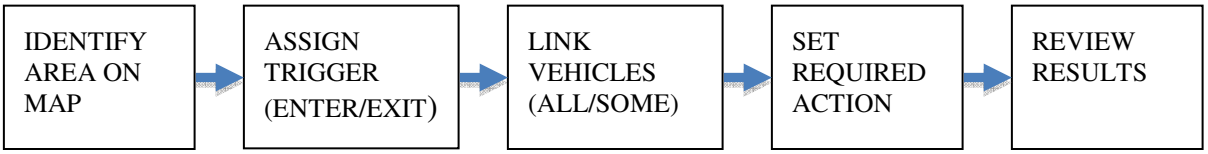


Figure 6. Possible actions to take when a zone has been breached

Another way of looking at this is depicted in the following:



Training

Including the idea that an airport can use GPS/GIS solutions for training purposes continues to evolve on the basis that training, versus basic situational awareness is very important in working towards a safety conscience culture at an airport. Airports have applied the technology to set routes for inspections so they are aware of how to proceed on the proper course, going the proper direction, at the proper speed while be reminded of the airport specific settings (hold line warnings for example). They have also used the same approach to allow record the behaviors of a vehicle operator on a driving test (i.e. did they stop where they were supposed to, did they obey the posted speed limits etc.). The system, once set, actually records and marks the individual operators performance and can generate the objective report that is desired.

Management Oversight

GPS/GIS systems operate very well in a stand-alone manner. For example, the lead snowplow may not need to communicate its positional data to anyone else and the functionality of the system for its specific purpose (navigation of the airfield) is perfectly addressed. Settings can be pre-loaded and sent with the vehicle hardware to the airfield as required. This can help management to ensure that operators who are not familiar with the airfield, have the benefit of the standard operating procedures.

There are situations that require collected data to be transferred back to a central location, either immediately and or at some time designated in the future. For example, the ARFF captain may wish to be able to view the location of crews at all times. This requires constant broadcast of data (there are several methods available here). This capability of being able to see where the crews are, and being connected to all assets allows GPS/GIS to drive tremendous advantages in terms of data storage (for use later as described above) and also for communications.

The data, stored as required allows management to be able to review activity and issues related to vehicle operation (for those vehicles that are equipped) and review trends and patterns in an objective manner. For example, it may be helpful to understand where any hold line issues are occurring over time, as a solution may be site specific versus being required across the entire airfield. This can save time and money as well as impactful to the airfield operators as the approach is based on data versus what could be considered conjecture.

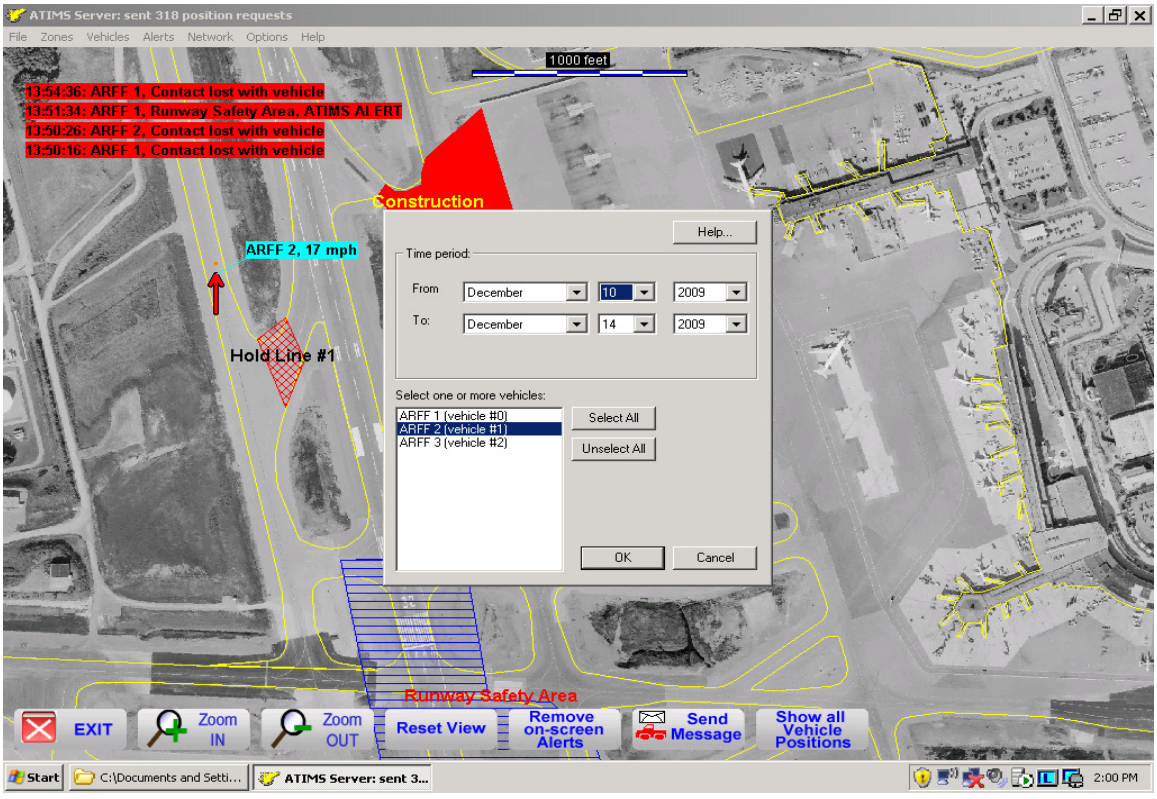


Figure 7. Running a time based report for a specific vehicle activity set

Future Developments

As actual airfield use and industry review of GPS/GIS technologies has taken place, the following developments seem logical and value added, at least in the author's opinion:

- Placing a zone around a vehicle to offer enhanced warnings. This allows a system to properly compensate for GPS signal latency. The zone should increase in size and possibly shape as vehicle speeds increase and decrease in the same manner as vehicle speeds decrease [3].

- Using certain tones to alert vehicle operators to certain conditions. Feedback across several airport users has indicated that tone style warnings are better in terms of recognition than voice style warnings due the similarity of voice style warnings to voices heard via radios and cell phones in the vehicle cab [4].

- Integration of other data sources. Systems that allow for the integration and viewing of data from other sources appear to have value to the situational awareness of both the vehicle operator, the operator's center and possibly air traffic control [5].

- Improved accuracy of WAAS GPS antenna's. Newer antenna currently being tested offer better accuracy than current WAAS antennas. In applications where the actual vehicle location position accuracy is needed, special receivers may be added to enhance this accuracy while not being overly expensive to deploy

Summary

GPS/GIS solutions are scalable in nature, which is important with respect to the value they can create for an airport, as each one is unique in terms of operational challenges, available budget, human resources etc. Good programs will allow airport operators to build on this technology over time, starting with their most pressing needs (for example, getting a handle on incursions) and adding to this over time, while never dictating processes and or reporting output as this should be customizable.

GPS/GIS solutions are intuitive and easy to use, making adoption relatively simple as the information/user interface is typically packaged in a familiar format (i.e. the high resolution image of the airfield is the backdrop).

Lastly, while GPS/GIS solutions offer obvious opportunities for airport operations, it is important that these technologies (and others for that matter) are used as support tools rather than being considered replacement solutions. They can help make well-documented processes more efficient and well-trained staff safer, but they cannot replace the need to continue to provide sound processes and proper training for airport operators.

References:

1) Flight Safety Foundation: Web articles, 2007.
2) Console, Sam. Comments from discussion, 2007.
3) FAA- William J. Hughes Technical Centre
4) Frisby, Dan- Comments from discussion, 2009
5) Botting, Mike- Comments from discussion, 2009

Special thanks to:

1) Jerry Bettendorf- El Paso International Airport
2) Sam Console- Philadelphia International Airport
3) Robert Gentile- Toronto Pearson International Airport
4) FAA- William J. Hughes Technical Centre
5) Dan Frisby- Anchorage International Airport
6) Mike Botting- NAVCANADA

Appendix #1:

What is GPS?

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS.

How it works.

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

How accurate is GPS?

Today's GPS receivers are extremely accurate, thanks to their parallel multi-channel design. 12 parallel channel receivers are quick to lock onto satellites when first turned on

and they maintain strong locks, even in dense foliage or urban settings with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. Most GPS receivers are accurate to within 15 meters on average.

Newer GPS receivers with WAAS (Wide Area Augmentation System) capability can improve accuracy to less than three meters on average. No additional equipment or fees are required to take advantage of WAAS. Users can also get better accuracy with Differential GPS (DGPS), which corrects GPS signals to within an average of three to five meters. The U.S. Coast Guard operates the most common DGPS correction service. This system consists of a network of towers that receive GPS signals and transmit a corrected signal by beacon transmitters. In order to get the corrected signal, users must have a differential beacon receiver and beacon antenna in addition to their GPS.

The GPS satellite system

The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. They are constantly moving, making two complete orbits in less than 24 hours. These satellites are traveling at speeds of roughly 7,000 miles an hour.

GPS satellites are powered by solar energy. They have backup batteries onboard to keep them running in the event of a solar eclipse, when there's no solar power. Small rocket boosters on each satellite keep them flying in the correct path.

Here are some other interesting facts about the GPS satellites (also called NAVSTAR, the official U.S. Department of Defense name for GPS):

1. The first GPS satellite was launched in 1978.
2. A full constellation of 24 satellites was achieved in 1994.
3. Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.
4. A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.
5. Transmitter power is only 50 watts or less.

What's the signal?

GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band. The signals travel by line of sight, meaning they will pass through clouds, glass and plastic but will not go through most solid objects such as buildings and mountains.

A GPS signal contains three different bits of information — a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information. You can view this number on the GPS unit's satellite page, as it identifies which satellites it's receiving.

Ephemeris data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits ephemeris data showing the orbital

information for that satellite and for every other satellite in the system.

Almanac data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position.

Source: www.garmin.com

What is a GIS?

A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. Practitioners also define a GIS as including the procedures, operating personnel, and spatial data that go into the system.

How does a GIS work?

Relating information from different sources

The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship. Most of the information we have about our world contains a location reference, placing that information at some point on the globe. When rainfall information is collected, it is important to know where the rainfall is located. This is done by using a location reference system, such as longitude and latitude, and perhaps elevation. Comparing the rainfall information with other information, such as the location of marshes across the landscape, may show that certain marshes receive little rainfall. This fact may indicate that these marshes are likely to dry up, and this inference can help us make the most appropriate decisions about how humans should interact with the marsh. A GIS, therefore, can reveal important new information that leads to better decision-making.

Source: www.usgs.gov